Water Sample
Data Documentation

Introduction

During the two Arabesque cruises over 200 different parameters were measured on water samples by 38 principal investigators using a wide range of protocols. The aim of this document is to allow the protocol used to obtain any particular data value within the BOTDATA table to be determined with ease.

To help you find the information you require quickly, the document is subdivided into sections that describe groups of closely related parameters. These are listed below as a series of hot links. Each section starts with the definition of the parameter codes covered, followed by a list of who measured one or more of those parameters. Next, there is a protocol section describing the methods used by each principal investigator. Finally, there may be comments on data quality that have been noted by BODC or have come to our attention.

<TIP> If you want to find out a how a particular parameter was measured and know the parameter code then the fastest way to find the information you require is to use the *Acrobat* 'find' tool to search for the parameter code. Then use the 'find' tool again to search for the name of the principal investigator. This will take you straight to the protocol description you require.

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References

Full references for the papers cited in the protocol descriptions.

Bacterial Production Abundance and Losses

Parameter Code Definitions

TBCCMDPZ	Total bacterial cell numbers per ml Optical microscopy of DAPI stained samples
CBCCMDPZ	Cyanobacteria cell numbers per ml Optical microscopy
UPLERIP4	Leucine uptake rate pmol/litre/hour Isotope doped incubation, 0.2µm Nuclepore filtered
UPTHRIP4	Thymidine uptake rate pmol/litre/hour Isotope doped incubation, 0.2µm Nuclepore filtered

Originator Code Definitions

3	Dr. A. Pomroy	Plymouth Marine Laboratory
105	Dr. T. Weisse	Max Planck Institute

Originator Protocols

Dr. A. Pomroy

Samples were collected from 10 depths corresponding to 97%, 55%, 32.6%, 19.9%, 13.8%, 6.9%, 4.6%, 3%, 2.1% and 1% of surface irradiance, using pre-dawn CTD casts.

Tritiated thymidine incorporation experiments followed the methods of Fuhrman and Azam (1982) and the leucine incorporation experiments followed the methods of Simon and Azam (1989), modified to include the cold trichloroacetic acid (TCA) extraction method of Chin-Leo and Kirchman (1988). Five replicate, 10 ml aliquots from each depth sampled were transferred to sterile, polystyrene, tissue-culture tubes and placed in an incubator in the dark, at *in situ* temperatures and allowed to acclimatise for 15 minutes prior to the addition of the isotope. Electron microscope grade glutaraldehyde was added to one replicate sample from each depth at a final concentration of 2.5% by volume to act as controls. ^{3}H-thymidine or ^{3}H-leucine was added to each tube to give final concentrations of 5 and 10 nM respectively.

The samples were incubated for one to one and a half hours, but time-course assays showed that incorporation was linear for two hours and frequently longer.

At the end of the incubation, samples were transferred to an ice/water bath and ice-cold trichloroacetic acid (TCA) added to give a final concentration of 5% by volume. The samples were left in the water bath for 15-30 minutes and filtered through 25mm 0.2 micron pore-size, track-etched, polycarbonate membrane filters. Each filter was rinsed five times with 1ml 5% ice-cold TCA, placed in a scintillation vial and stored in a desiccator with active silica gel for 24 hours. At the end of this period, the samples were counted in an LKB Rackbeta 1219 liquid scintillation counter. Counting efficiency was determined by an external standard, channels ratio method and checked by the occasional addition of internal standards.

Bacterial abundance

Samples were fixed with 2.5% by volume, 0.2 micron filtered, electron microscope grade glutaraldehyde, stained immediately with DAPI (4’6-diamidino-2-phenylindole) as described by Porter and Feig (1980) and filtered.

Samples were either examined immediately or stored frozen at -20 °C until being examined back at the laboratory. Fluorescent bacteria were counted with an epifluorescence microscope by the method of Hobbie et al. (1977). The microscope used was a Leitz Ortholux II equipped with a 50W HBO light source, Ploempak 2.2 fluorescence vertical illuminator with filter block A and an NPL Fluorotar 100/1.32 oil objective lens.

Dr. T. Weisse

Samples were collected from up to 10 depths on pre-dawn CTD casts and mixed to obtain one integrated sample of the euphotic zone. The nominal depth given refers to the shallowest depth sampled.

Up to five 300ml aliquots of the mixed water were poured into clean 500ml polycarbonate Erlenmeyer bottles, pre-filtered through a 100 micron screen to remove larger predators, inoculated and dark incubated at ambient temperatures for 1 hour.

The uptake of tritiated leucine labelled bacteria was measured by labelling with (4,5-^{3}H)Leucine of high specific activity (171 Ci/mmol) for 12 - 25 hours. After labelling, the bacteria were heat killed at a temperature of 70-80 °C and filtered onto 0.2 micron Nuclepore filters and resuspended in sterile filtered sea water. This suspension was added to the Erlenmeyer bottles in a ratio of 1:4 to 1:6 to the mixed water samples, to which Penicillin/Streptomycin antibiotics had been added. A control bottle was fixed with 1% final concentration buffered glutaraldehyde. After incubation for 1 hour, the samples were killed by adding 2ml of 5% ice-cold trichloroacetic acid (TCA) and rinsing 4 times with 2ml aliquots of 5% ice-cold TCA after sequential filtering onto 8, 1 and 0.2 micron Nuclepore filters. The filters were stored dry in 5ml scintillation vials for 24 hours. At the end of this period, 2.5ml OptiPhase ‘HisSafe’ scintillation cocktail was added and the samples were counted in an LKB Rackbeta 1219 liquid scintillation counter. Counting efficiency was determined by an external standard, channels ratio method and checked by the occasional addition of internal standards. The decline in bacteria cell numbers during the period of incubation was used as an independent measurement of total bacterial loss rates.

Dissolved Organic Carbon

Parameter Code Definitions

CORGCOD1 Dissolved organic carbon (µmoles/litre)
High temperature platinum catalytic oxidation (GF/F filtered)

SEOCCOD1 Dissolved organic carbon standard error (µmoles/litre)
High temperature platinum catalytic oxidation (GF/F filtered)

Originator Code Definitions

13 Dr A.E.J.Miller Plymouth Marine Laboratory

Originator Protocols

Samples were taken from the CTD rosette and filtered through GF/F filters. Ultra-clean handling techniques were used throughout.

The analytical technique involves the direct injection of acidified and decarbonated sea water onto a platinised alumina catalyst at high temperature (680-900 °C) under an atmosphere of oxygen or high purity air. Quantitative production of CO_2 gas allows DOC concentrations to be determined using a CO_2-specific infrared gas analyser (IRGA).

Analyses were undertaken at sea using a Shimadzu TOC-5000 HTCO analyser fitted with a LiCor Li6252 IRGA. This overcame the problems associated with using the standard TOC-5000 IRGA on an unstable platform.

Great care was taken to quantify blank signals generated at all stages of the analytical procedure and to correct the data for them.

A more detailed description of the protocols followed may be found in Miller et al (1993).

For total dissolved nitrogen (TDN), the analytical technique involves the direct injection of acidified and decarbonated sea water onto a platinised alumina catalyst at high temperature (680-900 °C) under an atmosphere of oxygen or high purity air. Quantitative production of the nitric oxide radical allows total dissolved nitrogen concentrations to be determined using a nitrogen-specific chemiluminescence detector.

Analyses were undertaken at sea using a Shimadzu TOC-5000 HTCO analyser fitted with an Antek 705-D chemiluminescence detector. The combustion products travelled through a Drierite trap (97% $CaSO_4$, 3% $CoCl_3$) and a membrane (permeation tube) drier to remove any trace of water. The dried nitric acid radical was then reacted with ozone to produce the excited chemiluminescent nitrogen species and passed to the detector. Each sample was injected four times with each injection cycle taking 5.5 minutes.

POC and PON

Parameter Code Definitions

CORGCZP1	Particulate organic carbon (acidified) Acid fumed then C/N analyser (GF/F filtered) Micromoles/litre
NTOTCNP1	Particulate total nitrogen (“PON”) Carbon/nitrogen analyser (GF/F filtered) Micromoles/litre

Originator Code Definitions

83 Dr. Tim Fileman, Plymouth Marine Laboratory

Originator Protocols

Dr, Tim Fileman

SAP collection

Challenger Oceanics *in situ* stand-alone pumps (SAPs) were used to sample particulate material. The instruments are operated by a programmable timer to ensure that the pump only operates when in position at the desired depth. Membrane filters with a 0.4 micron pore size were used to collect the particulate material. On recovery the filters were rinsed and dried in clean conditions.

Replicate 500 ml aliquots were taken from CTD rosette bottles or the underway non-toxic sea water supply. After an initial screening through a 200 micron mesh, to prevent spurious results caused by large zooplankton, the samples were filtered through 25mm GF/F filters. Additional aliquots were taken on some stations and filtered through 30 micron pore filters to give additional data for the >30 micron size fraction. Samples were frozen at -20 °C until analysed back at the laboratory.

The samples were acidified with sulphur dioxide to remove carbonates and then dried at 50 °C for 2 days. The samples were then encapsulated in squares of pre-combusted aluminium foil in a 4.5mm press.

The samples were analysed in a Carlo Erba NA1500 elemental analyser at a reactor temperature of 1030 °C and a helium carrier flow rate of 120 ml per minute. Calibration was effected with standards of acetanilide assayed on a calibrated Cahn 25 balance. Filter and sea water blanks were analysed and used to correct the data.

Nutrients

Parameter Code Definitions

NTRZAATX	Nitrate + nitrite concentration µmol/litre Colorometric autoanalysis (unfiltered)
NTRIAATX	Nitrite concentration µmol/litre Colorometric autoanalysis (unfiltered)
AMONAATX	Ammonium concentration µmol/litre Colorometric autoanalysis (unfiltered)
PHOSAATX	Phosphate concentration µmol/litre Colorometric autoanalysis (unfiltered)
SLCAAATX	Silicate concentration µmol/litre Colorometric autoanalysis (unfiltered)
UREAAATX	Urea concentration µmol/litre Colorometric autoanalysis (unfiltered)

Originator Code Definitions

62 Dr. E.M.S. Woodward Plymouth Marine Laboratory

Originator Protocols

Standard autoanalyser methods were used as described in Rees *et al* (1995) for the measurement of nitrate+nitrite, nitrite, phosphate, silicate and urea. A new semi-continuous fluorescence analytical technique was used for ammonia, capable of nanomolar detection levels. In oligotrophic water, a nanomolar chemiluminescent analysis system was used.

Carbonate System Parameters

Parameter Code Definitions

TCO2CBTX	Total dissolved inorganic carbon (TCO_2) µmol/litre Coulometric analysis (unfiltered)
PCO2GCO1	pCO_2 (parts per million) Gas chromatography; shower-head equilibrator

Originator Code Definitions

57	Dr C. Robinson	Plymouth Marine Laboratory
31	Dr. S. Knox	Plymouth Marine Laboratory

Originator Protocols

Dissolved inorganic carbon was measured coulometrically. The instrument used was a Coulometric Incs model 5011 coulometer as described in Robinson and Williams (1991). The mean analytical precision was estimated as 0.5 - 1 micromole/kg.

Carbon dioxide (pCO2) was measured using a 'shower head' type equilibrator from which the gas phase was sampled. The equilibrated gas was carried in hydrogen and passed over a catalyst which converts the carbon dioxide to methane. The gas stream was then passed to a flame ionisation detector (FID), Hewlett-Packard 5890A- GC which uses compressed air as the combustion make-up gas. Primary calibration was by reference to a volumetrically prepared standard (pure carbon dioxide in zero air). All data are given at *in situ* temperature and corrected for atmospheric pressure changes, in microatmospheres. Precision studies have shown a standard deviation of no more than 1.5 microatmospheres for this method; repeated measurements of standards show a typical coefficient of variation to be no more than 0.2%.

Pigments

Parameter Code Definitions

CPHLFLP1	Fluorometric chlorophyll-a µg/litre Fluorometric assay of acetone extract (GF/F filtered)
CPHLHPP1	HPLC chlorophyll a µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
CPHLPR01	Calibrated CTD chlorophyll µg/litre Aquatrakka fluorometer calibrated against HPLC samples
ALLOHPP1	Alloxanthin µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
BUTAHPP1	Butanoyloxyfucoxanthin µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
C1C2HPP1	Chlorophyll c1c2 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
CHLBHPP1	Chlorophyll b µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
CLC3HPP1	Chlorophyll c3 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
DIADHPP1	Diadinoxanthin µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
DVCAHPP1	Diavinyl chlorophyll a µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
FUCXHPP1	Fucoxanthin µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
HEXOHPP1	Hexanoyloxyfucoxanthin µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
PBA1HPP1	Phaeophorbide-a1 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
PBA2HPP1	Phaeophorbide-a2 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
PBA3HPP1	Phaeophorbide-a3 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)

PBA4HPP1	Phaeophorbide-a4 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
PERIHPP1	Peridinin µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
PTA1HPP1	Phaeophytin-a1 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
PTA2HPP1	Phaeophytin-a2 µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)
ZEOXHPP1	Zeaxanthin µg/litre Reverse-phase HPLC assay of acetone extract (GF/F filtered)

Originator Code Definitions

5 Dr R. Barlow Plymouth Marine Laboratory

Originator Protocols

Samples of one to two litres were taken from all shallow biogeochemistry CTD casts, filtered onto GF/F filters and immediately frozen in liquid nitrogen. The filters were extracted into 90% acetone, an aliquot was taken and injected onto a C-8 reverse phase column for high pressure liquid chromatographic (HPLC) separation and quantification of some 20 chlorophyll and carotenoid pigments, using both absorbance at 440nm and fluorescence (excitation at 405nm, emission at 670nm) detection.

Dimethylsulphide and its Precursors

Parameter Code Definitions

DMSOGCD4	Dissolved dimethylsulphoxide nanomoles/litre Gas chromatography on DMS released by enzyme digestion (Millipore prefiltered)
DMSPGCD4	Dissolved dimethylsulphoniopropionate nanomoles/litre Gas chromatography (Millipore prefiltered)
DMSXGCD4	Dissolved dimethylsulphide nanomoles/litre Gas chromatography (Millipore prefiltered)

Originator Codes

68 Dr. A. Hatton Univ. of East Anglia

Originator Protocols

Water samples were collected from the continuous pumped sea water supply or from 10 litre Go-Flo bottles attached to the CTD rosette, using 500 ml ground glass bottles sealed with ground glass stoppers to leave minimal head space. The water was supplied to the bottom of the bottle using a silicate tube and the water allowed to overflow to prevent bubble entrapment.

Samples were transferred to the ship's laboratory for immediate DMS analysis by purge and trap gas chromatography. A volumetric aliquot of water was injected into the purging vessel through a Millipore pad pre-filter. Trace gases were extracted from the water by a stream of high grade nitrogen which subsequently passed through a cold trap (-150°C) where the gases were concentrated before being heated and injected into the gas chromatograph.

The gases were analysed using a Chromosil 330 column, isothermal at 40°C with flame photometric detection (FPD). Full details are given in Turner *et al* (1990). All DMS analyses were completed on board ship. The instrument was calibrated at the start and end of each sampling run using a stock DMS standard.

An aliquot of the purged water sample was treated with 10M NaOH (to decompose DMSP to DMS). The dissolved DMSP was quantified as DMS as described above. The filter pad was also treated with 10M NaOH and the DMS released was quantified to give particulate DMSP.

A second aliquot of purged water was treated with a solution containing purified DMSO reductase, ethylenediaminetetraacetic acid (EDTA) and flavin mononucleotide (FMN) to convert DMSO into DMS. Dissolved DMSO was then determined as DMS as described above. Further details of this technique may be found in Hatton *et al* (1994).

Methane and Nitrous Oxide

Parameter Code Definitions

CH4DGCDX	Dissolved methane nanomoles/litre Single phase equilibration gas chromatography
CH4SGCDX	Dissolved methane saturation (%) Calculated from methane concentration
DN2OGCTX	Dissolved nitrous oxide (N2O) nanomoles/litre Single phase equilibration gas chromatography
SN2OGCTX	Dissolved nitrous oxide saturation (%) Calculated from nitrous oxide concentration

Originator Codes

22 Prof. N.J.P. Owens Univ. of Newcastle

Originator Protocols

The dissolved seawater concentrations of nitrous oxide and methane (both important greenhouse gases) was determined simultaneously to high precision using a fully automated headspace equilibration gas chromatographic technique.

Samples were collected in 1 litre glass volumetric flasks and allowed to overflow by at least three volumes. Immediately following collection, the samples were stabilised by the addition of 200µl 0.25M aqueous mercuric chloride and the flasks were stoppered and inverted to disperse the $HgCl_2$. Analysis followed immediately; the samples were thermally equilibrated to 25°C in a water bath and then equilibrated with a headspace of known nitrous oxide and methane. The equilibrated gases were dried and passed over a Carbosorb column to remove CO_2 before being separated on Porapak Q columns and injected into the carrier gas lines (ultra high purity nitrogen) of two Shimadzu GC 8A gas chromatographs. The first was equipped with a flame ionisation detector (FID) for the analysis of methane; the second with an electron capture detector (ECD) for the measurement of nitrous oxide.

Two high mixing ratio primary standards were used for calibration, containing 10ppmv nitrous oxide, 5.2 ppmv methane and 20ppmv nitrous oxide, 8.5ppmv methane respectively. For routine calibrations, four secondary standards were prepared from these primary standards by pressure dilution (Upstill-Goddard *et.al*. 1990); estimates for their accuracy are 1.5% for methane and 2% for nitrous oxide. Analytical precisions are better than 0.5% for nitrous oxide and 0.4% for methane.

Methylamines

Parameter Code Definitions

DIMAFITX	Dissolved dimethylamine concentration nanomoles/litre Flow injection gas diffusion (unfiltered)
MOMAFITX	Dissolved monomethylamine concentration nanomoles/litre Flow injection gas diffusion (unfiltered)
TRMAFITX	Dissolved trimethylamine concentration nanomoles/litre Flow injection gas diffusion (unfiltered)

Originator Code Definitions

71 Dr. S.W. Gibb Plymouth Marine Laboratory

Originator Protocols

Water samples were collected from the CTD casts using either 250 ml gas-tight polythene bottles or 100 ml glass syringes. The methylamine concentrations were determined on board using Flow Injection Gas Diffusion coupled to Ion Chromatography (FIGD-IC).

The FIGD-IC procedure is described in Gibb *et al* (1995). This is a novel technique that allows the simultaneous measurement of methylamines and ammonia at nanomolar levels. Briefly, the ammonia and methylamines were deprotonated to their free, volatile forms through alkali admixing (NaOH, pH>12) and selectively transferred by diffusion across a gas-permeable membrane into a dynamic, acidic acceptor stream in which they were enriched in their cationic forms. Chelation of the alkali earth metals in the samples with EDTA, under thermodynamically optimised conditions, was used to prevent the precipitation of their hydroxides under the elevated pH conditions. The enriched acceptor stream was then transferred directly into an ion chromatograph in which the NH_4^+ and methylamines were separated within 15 minutes in an acidic eluent and quantified by chemically suppressed conductimetric detection.

Dissolved Sulphur Hexafluoride

Parameter Code Definitions

DSF6GCDX — Dissolved sulphur hexafluoride (SF_6) femtomoles/litre
Gas chromatography- electron capture detection (unfiltered)

Originator Code Definitions

106 Dr. C. Law — Plymouth Marine Laboratory

Originator Protocols

Water samples were collected from the CTD casts using syringes. The samples were then injected into the sparge tower of the gas chromatograph under a vacuum (500mm Hg) and mixed with sparge gas (oxygen-free nitrogen). Degassing of SF_6 from the sample was accelerated by the drawing in and rapid expulsion of the sample through 0.5mm orifices. The sparged SF_6 was then passed through magnesium perchlorate followed by a Nafion drier to absorb any water vapour and then directed through a cryogenically cooled Porapak Q trap (Upstill-Goddard et.al. 1991) to be stripped. The trap containing the sparged SF_6 was then isolated and raised out of the propanol, being heated from -70°C to 80°C in 25 seconds and the sparged SF_6 was transported to the chromatographic column where it was eluted after 50 seconds and passed to the electron capture detector. Oxygen and similar eluents were retained by molecular sieve columns.

Calibration was by reference to standards prepared by pressure dilution (Upstill-Goddard et.al., 1991) of 0.1% SF_6 in nitrogen mixture (Spantech Products Ltd., UK) in 9.4 litre bottles. Calibration precision for each GC unit showed a mean standard deviation of 2.5% or better.

Dissolved Oxygen

Parameter Code Definitions

DOXYPR01	Calibrated CTD Beckmann oxygen probe micromoles/litre Beckmann probe calibrated against Winkler samples
DOXYWITX	Dissolved oxygen concentration micromoles/litre Winkler titration
OXYSBB01	Dissolved oxygen saturation (%) Benson & Krause algorithm from Beckmann probe data

Originator Codes

27 Dr. J. Dickson Univ. of Plymouth

Originator Protocols

Dr. J. Dickson

The technique used was the standard automated Winkler titration, as described in Williams and Jenkinson (1982).

British Oceanographic Data Centre

The oxygen probe concentrations and saturations in table BOTDATA have been obtained by extracting the data from the CTD **downcasts** corresponding to the bottle firing depths. The CTD system used was a Neil Brown Mk3B with a non-pulsed membrane Beckmann oxygen sensor. Oxygen data were calibrated against Jo Dickson's water bottle data.

Oxygen saturations were computed using calibrated temperature and salinity data and the algorithm of Benson and Krause (1984).

Hydrography

Parameter Code Definitions

ATTNZR01	Red light attenuance (per metre) 660nm transmissometer
POTMCV01	Potential temperature degrees Celsius Computed from CTD data using UNESCO function POTEMP
PSALBSTX	Bench salinometer salinity (PSU) Guildline Autolab salinometer
PSALST01	CTD salinity (PSU) Derived from CTD conductivity and temperature measurements
SIGTPR01	CTD sigma-theta Computed using UNESCO function SVAN (stearic volume anomaly)
TEMPRTNX	Reversing thermometer temperature (degrees Celsius) Digital SIS reversing thermometers, mounted on CTD bottle
TEMPST01	CTD temperature (degrees Celsius) CTD platinum resistance thermometer
TOKGPR01	Micromolar to micromoles/kg conversion factor Calculated from CTD data

Originator Code Definitions

1	W. Miller	Research Vessel Services
1	J. Wynar	Research Vessel Services

Originator Protocols

In most cases where the parameter code ends in '01', the values have been obtained by BODC software which extracts CTD **downcast** data corresponding to the bottle firing depths. This ensures an internally consistent data set across all cruises regardless of whether or not the upcast data were made available. The method is prone to errors if significant changes occur to water column structure during the cast. In all cases, further details about the CTD data may be obtained from the CTD document for the relevant cruise.

The conversion factor TOKGPR01 is 1000/(1000+sigma-theta) and is stored to allow sample data stored in concentration per litre to be converted to concentration per kilogram.

An RVS Neil Brown Mk 3B CTD was used with a SeaTech 25cm path length red light (661 nm) transmissometer fitted to the cage. Temperatures were checked against SIS digital reversing thermometers and salinity calibrated against bottle salinity data analysed on board on a Guildline Autolab salinometer. Transmissometer data were corrected for light source decay using the air readings during the cruise and the air readings quoted by the manufacturer (SeaTech).

Irradiance

Parameter Code Definitions

IRRDPP01	Downwelling 2-pi PAR irradiance (microEinsteins/square metre/second) Hemispherical photodiode light meter mounted on CTD frame
IRRUPP01	Upwelling 2-pi PAR irradiance (microEinsteins/square metre/second) Hemispherical photodiode light meter mounted on CTD frame

Originator Code Definitions

16 BODC

Originator Protocols

The data presented in the BOTDATA table are derived from CTD **downcast** data at the bottle firing depths. Note that the interpolation was done on log transformed data to allow a linear technique to be used.

The data were collected by Plymouth Marine Laboratory designed light meters based on a photodiode under a hemispherical translucent white plastic cap. The sensors were designed to collect light across the visible portion of the spectrum.

The light meters were fitted to the CTD frame with the downwelling instrument projecting above the top of the bottle rosette and the upwelling instrument attached to the base of the cage. This gave a physical separation of approximately two metres.

The data were logged as voltages and converted to W/m^2 using laboratory calibrations. The calibrations used were over five years old. The data were converted to $\mu E/m^2/s$ using an empirically derived conversion factor of 3.75.

Microzooplankton Biomass and Grazing

Parameter Code Definitions

MZBCMITX	Microzooplankton biomass (mg carbon/cubic metre) Calculated from cell numbers determined by optical microscopy
MZBNMITX	Microzooplankton abundance (cells/ml) Optical microscopy
P400E00A	Autotrophic nanoflagellates (2-20 µm) per mil Epifluorescence microscopy with DAPI/proflavine stain
P400E00B	Heterotrophic nanoflagellates (2-20 µm) per mil Epifluorescence microscopy with DAPI/proflavine stain

Originator Code Definitions

84 Dr. P.H. Burkill	Plymouth Marine Laboratory
41 E.S. Edwards	Plymouth Marine Laboratory

Originator Protocols

Water samples were obtained from water bottles deployed on a CTD rosette. These were fixed with 1% Lugol's iodine and the microzooplankton were counted using an image analysis system coupled to an inverted microscope. Fixed samples were gently mixed and sub-samples of 30-100 ml were concentrated overnight in sedimentation chambers. Each sample was examined at a magnification of x300 and all grazers > *circa* 10 microns were counted. Cells were identified to genus level whenever possible.

Live video work together with fluorescence microscopy at sea enabled the separation of heterotrophic dinoflagellates from phototrophic forms. All ciliates were assumed to be heterotrophic. In order to obtain a more accurate identification of some ciliates, Protargol silver staining was carried out on a number of samples.

The biomass was determined using methods detailed in JGOFS protocols (Burkill et al, 1994). The image analysis system was used to generate data on the surface area of each cell. These were converted to cell volume using geometric formulae and standard volume to carbon conversion factors were applied for different taxa. Individual cell carbon volumes were integrated for discrete taxa to determine the biomass of those taxa in each water sample.

Samples were also collected for the determination of nanoplankton (2-20 micron) abundance and biomass. Samples were fixed in 0.3% glutaraldehyde, dual stained with DAPI and proflavine and filtered onto 0.4 micron black polycarbonate filters. Cells were counted by epifluorescence microscopy. Heterotrophs were distinguished from autotrophs by the presence or absence of chlorophyll autofluorescence. 1-200 flagellate cells were counted per filter and cell dimensions were measured with an ocular micrometer.

Flagellate cell volumes were calculated assuming they were ellipsoids. Biovolumes were converted to biomass using appropriate carbon conversion factors.

Natural microbial populations were incubated either *in situ* or on board ship using the dilution technique described by Landry and Hassett (1982). Time course experiments were run under different dilutions and the specific growth of phytoplankton determined. Water samples were collected at dawn from a depth of 10m using 30 litre Niskin bottles. Half of this water was filtered using a Gelman 0.2 micron mini capsule filter. A known volume of this 'predator and prey free' water was added to polycarbonate bottles. Each bottle was gently topped up with 200 micron screened, unfiltered water generating triplicate dilutions of 100%, 70%, 40% and 10%. Incubation was carried out over 24 hours. Subsamples were taken from each bottle at T_0 and T_{24} for determination of chlorophyll and fixation in Lugol's iodine for estimation of microzooplankton abundance. Chlorophyll was determined by extraction of 90% acetone, using a highly sensitive fluorometer. Phytoplankton mortality due to grazing was determined from alteration in the specific growth rate.

Qualitative analysis of microzooplankton herbivory was determined by incubating natural microbial populations with different types of fluorescently labelled algae (FLA). Cultured algae were heat stained with a fluorochrome, 5-(4,6-dichlorotriazan-2-yl) aminofluorescein (DTAF). Water samples were inoculated with FLA stock and experiments run for 60 minutes. Subsamples were collected over the experimental period and fixed in 1% Lugol's iodine. Up to 110 ml of sample were settled for 24 hours prior to analysis and the Lugol's coloration cleared with sodium thiosulphate. The FLAs present in each microzooplankton cell were counted and FLA uptake rates were calculated from the change in the average number of FLAs per individual with time. The mean cellular uptake rates were calculated for those taxa taking up FLAs in each experiment.

Phytoplankton

Parameter Code Definitions

P002M00Z	*Actinocyclus spp*. Optical microscopy	per mil
P012M00Z	*Asteromphalus spp*. Optical microscopy	per mil
P012M02Z	*Asteromphalus sarcophagus* Optical microscopy	per mil
P018M04Z	*Bacteriastrum furcatum* Optical microscopy	per mil
P018M05Z	*Bacteriastrum elongatum* Optical microscopy	per mil
P018M06Z	*Bacteriastrum solitarium* Optical microscopy	per mil
P021M06Z	*Biddulphia mobiliensis* Optical microscopy	per mil
P028M01A	*Cerataulina pelagica* (30µm) Optical microscopy	per mil
P028M01Z	*Cerataulina pelagica* Optical microscopy	per mil
P030M00C	*Chaetoceros* resting spores Optical microscopy	per mil
P030M00Z	*Chaetoceros* spp. Optical microscopy	per mil
P030M01Z	*Chaetoceros affine* Optical microscopy	per mil
P030M02A	*Chaetoceros atlanticum v. neapol*. Optical microscopy	per mil
P030M04Z	*Chaetoceros boreale* Optical microscopy	per mil
P030M05Z	*Chaetoceros breve* Optical microscopy	per mil

P030M09Z	*Chaetoceros compressum* Optical microscopy	per mil
P030M14Z	*Chaetoceros costatum* Optical microscopy	per mil
P030M19Z	*Chaetoceros decipiens* Optical microscopy	per mil
P030M20Z	*Chaetoceros densum* Optical microscopy	per mil
P030M21Z	*Chaetoceros didymum* Optical microscopy	per mil
P030M36Z	*Chaetoceros laciniosum* Optical microscopy	per mil
P030M39Z	*Chaetoceros messanense* Optical microscopy	per mil
P030M43Z	*Chaetoceros peruvianum* Optical microscopy	per mil
P030M70Z	*Chaetoceros anastomosans* Optical microscopy	per mil
P030M72Z	*Chaetoceros diversus* Optical microscopy	per mil
P030M73Z	*Chaetoceros dadayii* Optical microscopy	per mil
P030M74Z	*Chaetoceros debilis* Optical microscopy	per mil
P030M75Z	*Chaetoceros lauderi* Optical microscopy	per mil
P030M77Z	*Chaetoceros similis* Optical microscopy	per mil
P030M80Z	*Chaetoceros saltans* Optical microscopy	per mil
P033M01A	*Corethron criophillum* (15µm) Optical microscopy	per mil
P033M01Z	*Corethron criophillum* Optical microscopy	per mil

P034M01Z	*Coscinodiscus africanus* Optical microscopy	per mil
P034M22Z	*Coscinodiscus oculis-iridis* Optical microscopy	per mil
P034M28Z	*Coscinodiscus thorii* Optical microscopy	per mil
P040M02Z	*Detonula pumila* Optical microscopy	per mil
P048M01Z	*Eucampia zoodiacus* Optical microscopy	per mil
P048M02Z	*Eucampia cornuta* Optical microscopy	per mil
P052M00Z	*Fragilaria* spp. Optical microscopy	per mil
P058M00Z	*Guinardia* spp. Optical microscopy	per mil
P061M01Z	*Hemiaulus hauckii* Optical microscopy	per mil
P062M01Z	*Hemidiscus cuneiformis* Optical microscopy	per mil
P067M02Z	*Lauderia annulata* Optical microscopy	per mil
P068M01Z	*Leptocylindrus danicus* Optical microscopy	per mil
P068M02Z	*Leptocylindrus mediterranea* Optical microscopy	per mil
P072M00A	Pennates(small) Optical microscopy	per mil
P072M00C	Pennate (50µm) Optical microscopy	per mil
P073M10Z	*Navicula planamembranacea* Optical microscopy	per mil
P074M00A	*Nitzschia* spp. (70µm) Optical microscopy	per mil

P074M07Z	*Nitzschia bicapitata* Optical microscopy	per mil
P074M14Z	*Nitzschia closterium* Optical microscopy	per mil
P074M18Z	*Nitzschia delicatissima* Optical microscopy	per mil
P074M61Z	*Nitzschia seriata* Optical microscopy	per mil
P081M01Z	*Planktoniella sol* Optical microscopy	per mil
P084M00Z	*Pleurosigma* spp. Optical microscopy	per mil
P084M10Z	*Pleurosigma directa* Optical microscopy	per mil
P084M25Z	*Pleurosigma planktonicum* Optical microscopy	per mil
P087M00Z	*Porosira* spp. Optical microscopy	per mil
P087M02Z	*Porosira dentuculata* Optical microscopy	per mil
P093M02E	*Rhizosolenia alata* (15µm) Optical microscopy	per mil
P093M02F	*Rhizosolenia alata* (2µm) Optical microscopy	per mil
P093M02G	*Rhizosolenia alata* (5µm) Optical microscopy	per mil
P093M02Z	*Rhizosolenia alata* Optical microscopy	per mil
P093M06Z	*Rhizosolenia bergonii* Optical microscopy	per mil
P093M09Z	*Rhizosolenia cylindrus* Optical microscopy	per mil
P093M10Z	*Rhizosolenia calcar-avis* Optical microscopy	per mil

P093M11Z	*Rhizosolenia castracanei* Optical microscopy	per mil
P093M13Z	*Rhizosolenia fragilissima* Optical microscopy	per mil
P093M14C	*Rhizosolenia hebetata semispina* Optical microscopy	per mil
P093M20Z	*Rhizosolenia robusta* Optical microscopy	per mil
P093M21Z	*Rhizosolenia setigera* Optical microscopy	per mil
P093M22A	*Rhizosolenia shrubsolei* (10µm) Optical microscopy	per mil
P093M22B	*Rhizosolenia shrubsolei* (5µm) Optical microscopy	per mil
P093M22Z	*Rhizosolenia shrubsolei* Optical microscopy	per mil
P093M23A	*Rhizosolenia stolterfothii* (large) Optical microscopy	per mil
P093M23B	*Rhizosolenia stolterfothii* (small) Optical microscopy	per mil
P093M23Z	*Rhizosolenia stolterfothii* Optical microscopy	per mil
P093M24Z	*Rhizosolenia styliformis* Optical microscopy	per mil
P096M01Z	*Roperia tessellata* Optical microscopy	per mil
P101M01Z	*Skeletonema costatum* Optical microscopy	per mil
P102M07Z	*Stauroneis membranacea* Optical microscopy	per mil
P110M01Z	*Thalassionema nitzschiodes* Optical microscopy	per mil
P110M02Z	*Thalassionema bacillaris* Optical microscopy	per mil

P111M00A	*Thalassiosira* spp. (10µm) Optical microscopy	per mil
P111M00B	*Thalassiosira* spp. (20µm) Optical microscopy	per mil
P111M00C	*Thalassiosira* spp. (40µm) Optical microscopy	per mil
P111M00E	*Thalassiosira* spp. (4µm) Optical microscopy	per mil
P111M00F	*Thalassiosira* spp. (30µm) Optical microscopy	per mil
P111M00G	*Thalassiosira* spp. (45µm) Optical microscopy	per mil
P111M00H	*Thalassiosira* spp. (120µm) Optical microscopy	per mil
P111M00I	*Thalassiosira* spp. (2µm) Optical microscopy	per mil
P112M01Z	*Thalassiothrix frauenfeldii* Optical microscopy	per mil
P112M03Z	*Thalassiothrix delicatula* Optical microscopy	per mil
P200M00Z	Dinoflagellates Optical microscopy	per mil
P207M01Z	*Amphisolenia bidentata* Optical microscopy	per mil
P207M02Z	*Amphisolenia globosa* Optical microscopy	per mil
P213M04Z	*Ceratium candelabrum* Optical microscopy	per mil
P213M05Z	*Ceratium extensum* Optical microscopy	per mil
P213M08Z	*Ceratium furca* Optical microscopy	per mil
P213M09Z	*Ceratium fusus* Optical microscopy	per mil

P213M13Z	*Ceratium horridum* Optical microscopy	per mil
P213M18Z	*Ceratium macroceros* Optical microscopy	per mil
P213M26Z	*Ceratium tripos* Optical microscopy	per mil
P213M30Z	*Ceratium boehmii* Optical microscopy	per mil
P213M33Z	*Ceratium praelongum* Optical microscopy	per mil
P213M34Z	*Ceratium teres* Optical microscopy	per mil
P213M38Z	*Ceratium ranipes* Optical microscopy	per mil
P213M39Z	*Ceratium schroederi* Optical microscopy	per mil
P219M03Z	*Dinophysis brevisulcus* Optical microscopy	per mil
P219M16Z	*Dinophysis doryphorum* Optical microscopy	per mil
P219M18Z	*Dinophysis favus* Optical microscopy	per mil
P228M14Z	*Gonyaulax milneri* Optical microscopy	per mil
P228M17Z	*Gonyaulax polygramma* Optical microscopy	per mil
P228M19Z	*Gonyaulax spinifera* Optical microscopy	per mil
P229M00Z	*Gymnodinium* spp.(autotrophic) Optical microscopy	per mil
P229M50Z	*Gymnodinium splendens* Optical microscopy	per mil
P229M91Z	*Gymnodinium* A (autotrophic) Optical microscopy	per mil

P230M01Z	*Gyrodinium aureolum* Optical microscopy	per mil
P230M11Z	*Gyrodinium falcatum* Optical microscopy	per mil
P235M00Z	*Heteraulacus* spp. Optical microscopy	per mil
P257M04Z	*Prorocentrum compressum* Optical microscopy	per mil
P257M06Z	*Prorocentrum gracile* Optical microscopy	per mil
P257M07Z	*Prorocentrum triestinum* Optical microscopy	per mil
P257M09Z	*Prorocentrum minimum* Optical microscopy	per mil
P266M00Z	*Scrippsiella* spp. Optical microscopy	per mil
P315M00Z	*Cochlodinium* spp. Optical microscopy	per mil
P322M00Z	*Diplopsalopsis* spp. Optical microscopy	per mil
P329M00Z	*Gymnodinium* spp. (heterotrophic) Optical microscopy	per mil
P330M04Z	*Gyrodinium britannicum* Optical microscopy	per mil
P330M14Z	*Gyrodinium fusiforme* Optical microscopy	per mil
P330M15A	*Gyrodinium glaucum* (small) Optical microscopy	per mil
P330M15Z	*Gyrodinium glaucum* Optical microscopy	per mil
P339M00Z	*Kofoidinium* spp. Optical microscopy	per mil
P345M00A	*Noctiluca* spp. (juvenile) Optical microscopy	per mil

P345M00B	*Noctiluca* spp. (motile) Optical microscopy	per mil
P345M01Z	*Noctiluca scintillans* Optical microscopy	per mil
P349M00Z	*Oxytoxum* spp. Optical microscopy	per mil
P349M01Z	*Oxytoxum scolopax* Optical microscopy	per mil
P353M01Z	*Podolampas bipes* Optical microscopy	per mil
P353M02Z	*Podolampas palmipes* Optical microscopy	per mil
P356M00Z	*Pronoctiluca* spp. Optical microscopy	per mil
P358M15Z	*Protoperidinium curtipes* Optical microscopy	per mil
P358M42Z	*Protoperidinium oceanicum* Optical microscopy	per mil
P358M54Z	*Protoperidinium steinii* Optical microscopy	per mil
P358M55Z	*Protoperidinium elegans* Optical microscopy	per mil
P360M01Z	*Ptychodiscus noctiluca* Optical microscopy	per mil
P361M01Z	*Pyrocystis lunula* Optical microscopy	per mil
P361M03Z	*Pyrocystis fusiformis* Optical microscopy	per mil
P361M04Z	*Pyrocystis noctiluca* Optical microscopy	per mil
P366M00A	Peridinians (large) Optical microscopy	per mil
P366M00B	Peridinians (small) Optical microscopy	per mil

P370M00A	*Torodinium* spp. (small) Optical microscopy	per mil
P370M01Z	*Torodinium robustum* Optical microscopy	per mil
P371M00Z	*Warnowia* spp. Optical microscopy	per mil
P400M00A	Flagellate 2µm Optical microscopy	per mil
P400M00B	Flagellate 4µm Optical microscopy	per mil
P404M04Z	Cryptomonad Optical microscopy	per mil
P410M00A	Holococcolithophorid 10µm Optical microscopy	per mil
P410M02A	Holococcolithophorid (small) Optical microscopy	per mil
P411M01Z	*Acanthoica quattrospina* Optical microscopy	per mil
P412M01Z	*Anoplosolenia brasiliensis* Optical microscopy	per mil
P413M01Z	*Anthosphaera robusta* Optical microscopy	per mil
P415M02Z	*Calciopappus rigidus* Optical microscopy	per mil
P416M01Z	*Calciosolenia murrayi* Optical microscopy	per mil
P417M00Z	*Calyptrosphaera* spp. Optical microscopy	per mil
P427M00Z	*Halosphaera* spp. Optical microscopy	per mil
P428M01Z	*Helicosphaera carteri* Optical microscopy	per mil
P432M01Z	*Michaelsarsia elegans* Optical microscopy	per mil

P433M00Z	*Ophiaster* spp. Optical microscopy	per mil
P436M00Z	*Phaeocystis* spp. Optical microscopy	per mil
P439M00Z	*Pterosperma* spp. Optical microscopy	per mil
P445M00A	*Syracosphaera* spp. (10 µm) Optical microscopy	per mil
P445M00B	*Syracosphaera* spp. A (20 µm) Optical microscopy	per mil
P445M00C	*Syracosphaera* spp. B (20 µm) Optical microscopy	per mil
P445M06Z	*Syracosphaera pulchra* Optical microscopy	per mil
P448M01Z	*Emiliana huxleyi* Optical microscopy	per mil
P449M00Z	*Gephyrocapsa* spp. Optical microscopy	per mil
P449M01Z	*Gephyrocapsa oceanica* Optical microscopy	per mil
P452M02Z	*Umbellosphaera irregularis* Optical microscopy	per mil
P500M17Z	Ciliates Optical microscopy	per mil
P510M01Z	Bodonids Optical microscopy	per mil
P521M05B	*Mesodinium* spp. (medium) Optical microscopy	per mil
P521M05C	*Mesodinium* spp. (small) Optical microscopy	per mil
P981M00Z	*Halopappus* spp. Optical microscopy	per mil
P982M00Z	*Erythopsis* spp. Optical microscopy	per mil

P983M01Z	*Umbillicosphaera sibogae* Optical microscopy	per mil
P984M01Z	*Trichodesmium thibauthii* Optical microscopy	per mil
P985M00A	*Strombidium* spp. (large) Optical microscopy	per mil
P985M00B	*Strombidium* spp. (small) Optical microscopy	per mil
P985M00C	*Strombidium* spp. (medium) Optical microscopy	per mil
P986M00Z	*Pyramimonas* spp. Optical microscopy	per mil
P987M01Z	*Pachyneis gerlachii* Optical microscopy	per mil
P988M01Z	*Ornithocercus quadratus* Optical microscopy	per mil
P989M00Z	*Oolithus* spp. Optical microscopy	per mil
P990M01Z	*Histoneis hyalina* Optical microscopy	per mil
P991M01Z	*Florisphaera profunda* Optical microscopy	per mil
P992M01Z	*Crenalithus sessilis* Optical microscopy	per mil
P993M01Z	*Climacodium frauenfeldii* Optical microscopy	per mil
P994M01Z	*Ceratocorys horrida* Optical microscopy	per mil
P995M01Z	*Calcidiscus leptoporus* Optical microscopy	per mil
P996M00Z	*Brachydinium* spp. Optical microscopy	per mil
P997M00Z	*Asterolampra* spp. Optical microscopy	per mil

Originator Codes

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Originator Protocols

Water samples were taken from bottles deployed on the CTD and preserved in Lugol’s Iodine. Back in the laboratory, sedimented samples were examined by optical microscopy and the dominant species in the >5 micron size fraction were quantified.

Automated Flow Cytometry

Parameter Code Definitions

CBCCAFTX	Cyanobacteria cell numbers Automated flow cytometry	per mil
PYEUAFTX	Eukaryotic cell numbers Automated flow cytometry	per mil
PYPKAFTX	Prokaryotic cell numbers Automated flow cytometry	per mil
PYTTAFTX	Total cell numbers Automated flow cytometry	per mil

Originator Code Definitions

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104 Dr. G.Tarran	Plymouth Marine Laboratory

Originator Protocols

Samples were collected from all available depths of the shallow biogeochemistry CTD casts and a 400 microlitre aliquot was injected into a Becton Dickinson FACSort cytometer. Sensitivity was sufficient to determine cellular light scatter and fluorescences from prochlorophytes (0.6 micron size, approximate chlorophyll a content 1 femtogram) in surface waters. Protocols based on light scatter and fluorescence were used to characterise and quantify total phytoplankton concentrations and those of individual taxa (prochlorophytes, cyanobacteria and picoeukaryotes).

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